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STUDY OF TIME LAPSE PROCESSING
FOR DYNAMIC HYDROLOGIC CONDITIONS

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Type II Progress Report for the
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TYPE II PROGRESS REPORT

A) Title: STUDY OF TIME-LAPSE DATA PROCESSING FOR DYNAMIC HYDROLOGIC CONDITIONS

B) ERTS-A Proposal 342-B GSFC ID PR154

C) INTRODUCTION

Under ERTS-A Proposal 342-B SRI has been charged with demonstrating and further exploring the use of electronic techniques in converging upon quantitative descriptions of hydrologic and hydrologic related phenomena of satellite imagery obtained from the ERTS satellite. The efforts have been directed toward the specific data processing needs of a group of ERTS principal investigators within the U.S. Geological Survey (Water Resources Division) operating in widely diverse specialities but all part of the W. R. D. program in Dynamic Hydrology. This is a report of that effort accomplished between 6 March and 6 September 1973.

D) PREVIOUS AND CURRENT ACTIVITIES

1. Hardware

Three important additions to the ESIAC circuitry can be reported: capability for grey-scale storage on same video disc track as main image, the construction of a semiconductor binary memory mask store (scratchpad memory) and a two-dimensional color space display.

a) Grey-scale storage

This new capability permits the storing of the grey-scale and annotation block from an ERTS frame during the vertical retrace period of the television signal. This results in a valuable saving in recording space on the magnetic disc. An additional advantage is that when the main image area is being used to display a magnified (zoomed-in) segment from a full ERTS frame, the pertinent radiometric calibration data for the frame--at zero zoom--is still available (by "rolling" the image vertically to display the normal vertical blanking interval).

Any gain, dc offset, or amplitude comparison experienced by the main signal during the storage and reproduction process is also experienced by the calibration waveform.

b) Binary Memory Mask. (Scratchpad Memory)

Figure I is a block diagram of ESIAC showing the new binary mask memory (scratchpad memory) as a shaded box. This semiconductor memory serves for storing and editing binary thematic image masks and provides the capability for simultaneous time-lapsed color imagery plus providing for area measurements of this imagery. These aspects of the system were discussed in previous progress reports.

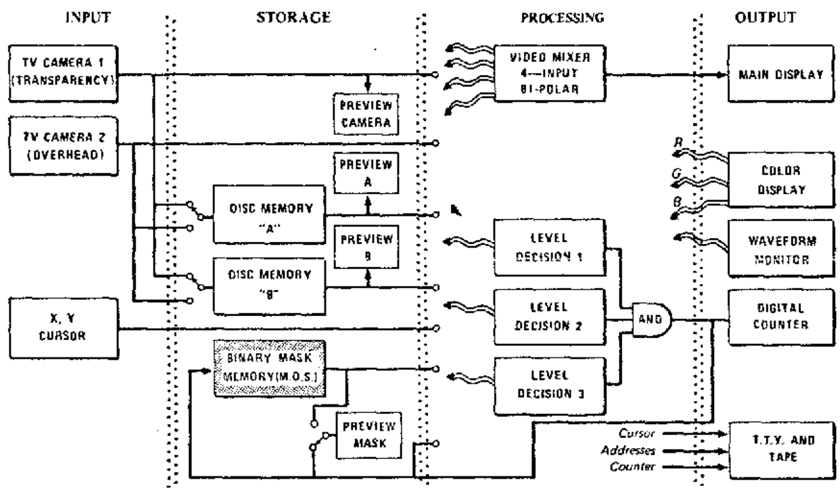

FIG. 1 BLOCK DIAGRAM OF ESIAC

c) Two-dimensional Color Space Display

A description of this display capability is given in some detail in the Appendix to this report. In brief, the new display is an oscilloscope with matched wideband x and y deflector amplifiers. This arrangement provides a dynamic version of the two-dimensional diagram frequently used for analysis of two-band radiometry. It is particularly useful for (a) identifying amplitude-spectral combinations generated by training region in real ERTS data and (b) adjusting the various thresholding, slicing, and ratioing controls to make thematic extractions.

2. Data Processing

The following data processing activities and techniques undertaken for the participating investigators can be reported:

a) For Dr. F. Mark (IN045) U.S. Geological Survey, Tacoma, Washington: Areal snow measurements were requested for Mt. Rainier and selected basins in the Cascade Mountain region using sequential ERTS scenes of 29 July, 16 August, 2 September, 8 October, 14 November, 2 December 1972, plus 6 January, 25 January and 11 February 1973. The aforementioned areas are of very rugged terrain and present formidable challenges to the measurement of snow cover. Special problems include the changing spectral responses of snow during changing seasons with underlying terrain (rock or forest coverage) and varying degrees of shadowing.

The first approach used on ESIAC was to evaluate the amount of snow via simple radiance thresholding in a single spectral band. This procedure was reported upon in the Type II Progress Report spanning the period 6 October 1972 - 6 March 1973. In this approach a "best visual estimate" (BVE) of the amount of snow in the image is obtained by setting the thresholder on ESIAC to generate a video-derived mask until a visual match is obtained with the snow cover in the displayed scene. The area of the mask is then obtained by counting the TRUE pixels in a digital counter. For analysis purposes these BVE values are presented along with curves such as those of Figure 2 which show typical data for the same region of Mt. Rainier, Washington on nine different dates.

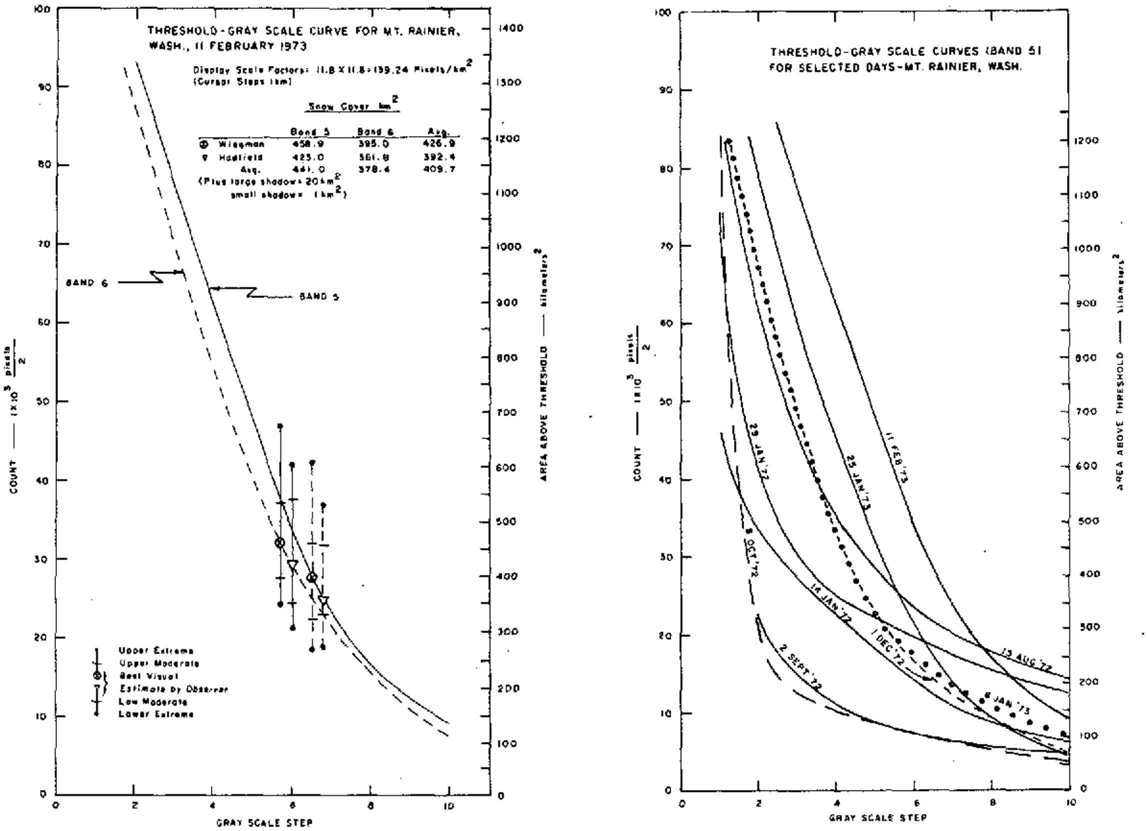

FIG. 2 EXAMPLES OF THRESHOLD GREY-SCALE CURVES

The curves themselves were derived purely objectively by plotting area-above-threshold versus threshold level setting. Plot points, where shown, are the "best visual estimates" (BVE's) for two different operators. Variance bars are shown for two widely different sets of instructions. The narrower range ("moderate tolerance") indicates the range of settings which the operator was willing to accept as being nearly as probable as his preferred, or BVE setting. The full length of the bars indicates an extreme range within which the operator felt very sure that the true area would be found. It has been found that the BVE's tend to fall on or very near a very steep portion of the curve, indicating an undesirably high sensitivity of the area measurement to the threshold level setting. This technique yields reading variances due to different criteria between operators or from the use of different evaluation criteria by the same operator. These variances typically amounted to about ±50 km^2 for a snowfield area of 400 km^2, or ±12.5% of the reading.

In an attempt to reduce these variances, other measurement techniques were tried. One such approach was the date-to-date differencing of snow cover. An example of this technique* is illustrated in Figure 3 (panels a to e) for Mt. Rainier, Washington. Image A shows snow cover near its yearly minimum. Image B shows the addition of new snow.* Image C is a TV display of the result of subtracting the video signal for Image A from the video signal of Image B. Those areas where there has been no significant radiance change cancel to a mid-grey appearance (regardless of whether the original scene content had been bright and dark). Anything whiter than the mid-grey level in Image C is interpreted as being new snow (or cloud). Conversely, the dark-grey-to-black regions indicate regions where the radiance had decreased significantly during the 37 day-period. Images D and E of Figure 3 show binary masks derived by "slicing" (thresholding) the difference signal of Image C. The white or "true" regions of each mask is then measured separately by a digital pixel counter.

As with the procedure for measuring areas on each given date, this technique also shows the need for some subjective judgment in interpretation but it is possible that measuring differences directly may yield more representative values than obtaining differences by subtracting the measurements of snow made on two different dates.

An additional approach being considered involves the concept of estimating snowpack by assigning an Equivalent Snow Elevation.

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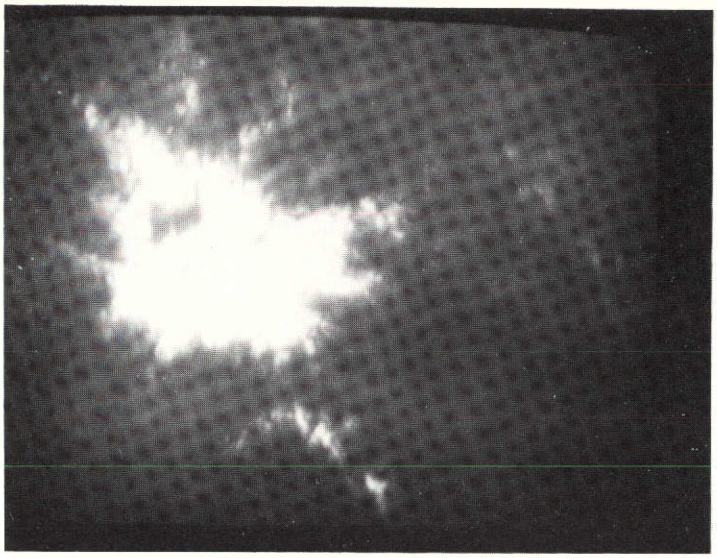
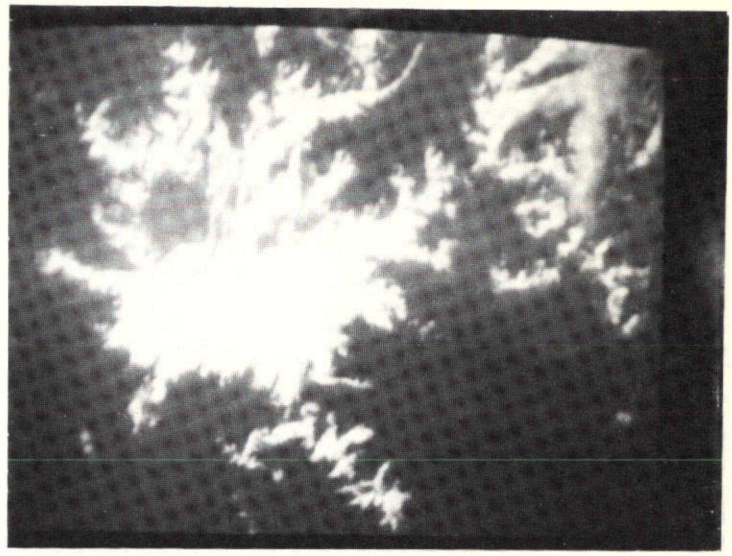
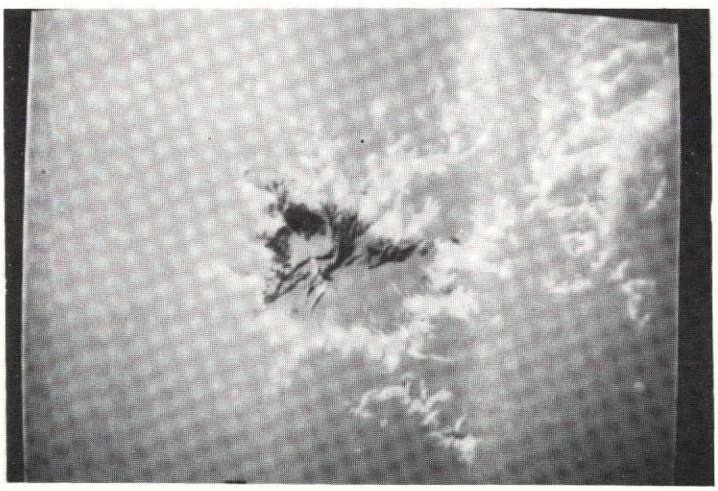
*A description of this technique is given in Type I Progress Report for the Period 6 March - 6 May 1973.



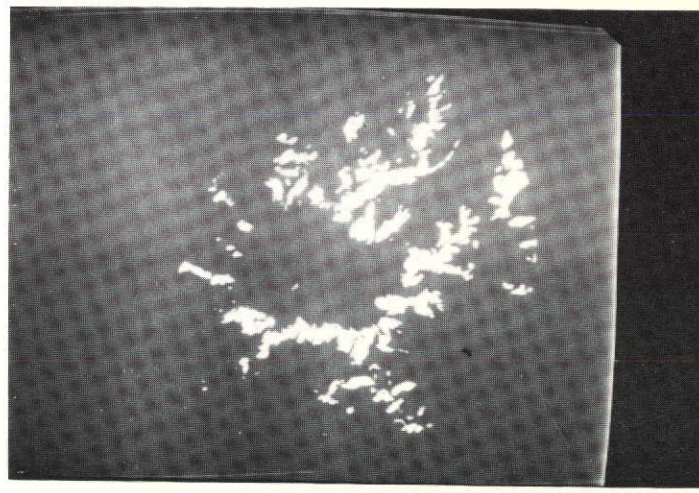
(a) MT RAINIER, WASH. 8 OCTOBER 1972
1077-18-260-5



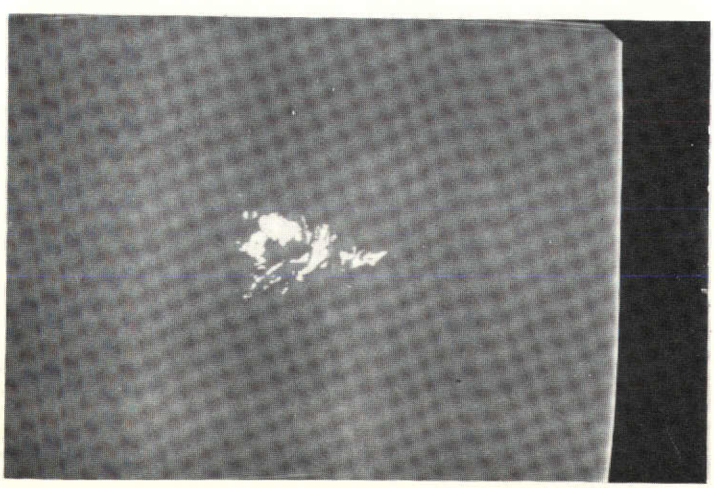
(b) MT RAINIER, WASH 14 NOVEMBER 1972
1114-18-322-5



(c) CONTINOUS TONE DISPLAY OF DATE TO DATE IMAGE DIFFERENCING (MSS-5) 14 NOVEMBER-8 OCTOBER 1972



(d) 14 NOVEMBER-8 OCTOBER 1972 BINARY MASKS OF WHITE REGIONS OF FIG. C



(e) 8 OCTOBER-14 NOVEMBER 1972 BINARY MASKS OF BLACK REGIONS OF FIG. C

FIGURE 3 DATE TO DATE DIFFERENCING TECHNIQUE

This technique has gained some acceptance in snow hydrology and in fact detailed tables of area versus elevation are already available for some areas. One conceptual approach for using ESIAC to estimate the Equivalent Snowline Elevations is to permit the operator to rapidly cycle through a set of registered binary masks, each mask depicting all areas above a specified threshold elevation see Fig. 4. The mask

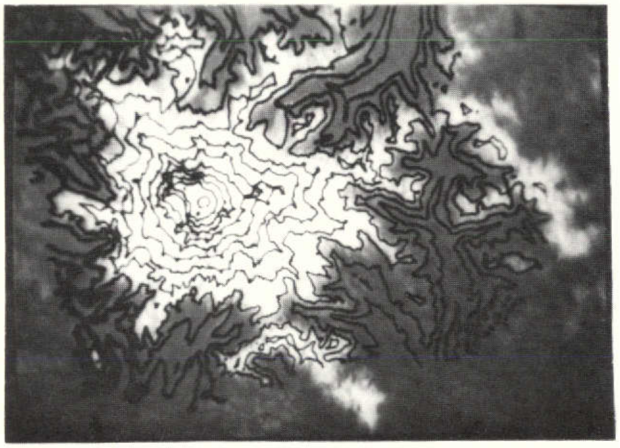


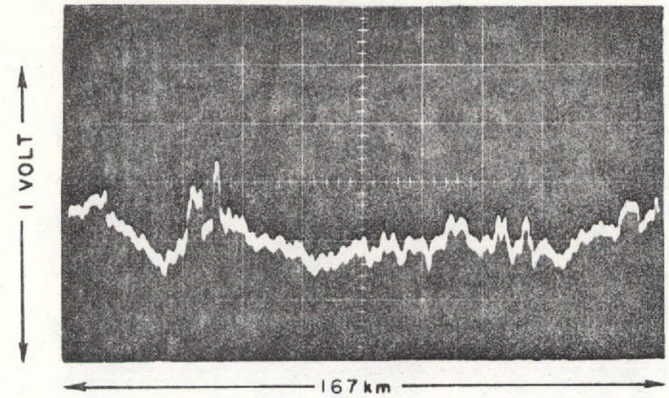
FIG. 4 ESIAC DISPLAY SHOWING 1000-ft CONTOURS OF MT. RAINIER, WASHINGTON, ELECTRONICALLY SUPERIMPOSED ON 30-km SECTION OF ERTS IMAGE NO. 1005-18260-5 FOR 29 JULY 1972. (Central Contour is 14,000 ft)

which provides the best visual match to the snowpack would then define the Equivalent Snowline Elevation. Several procedural alternatives for generating the required dynamic mask are being considered, and at least one will soon be implemented to test the efficacy of the general concept. Experiments with this approach are still continuing.

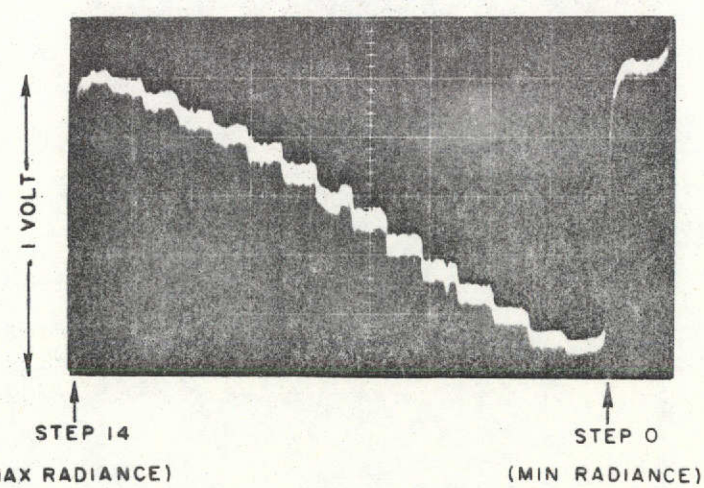
On the 8th of June, Messrs. W. Evans and S. M. Serebreny of SRI visited Dr. Meier and staff at Tacoma for discussions about many aspects of snow measurements from ERTS imagery over mountainous terrain, particularly with respect to questions of ground truth data reduction and measurement variances. Currently, details of U2 imagery of the Mt. Rainier area are being studied at SRI in color and color stereo to establish more definitive rules about how to set the slicing threshold when measuring ERTS images on the ESIAC. An analysis of the digital tapes for this area is also being conducted.

b) For Dr. Raymond M. Turner (IN411) U.S. Geological Survey, Tucson, Arizona: Due to the location of his test sites, Dr. Turner has now accumulated the largest file of sequential imagery, some 14 cycles of usable data, of any of our investigators. Systematic changes in areal extent of the vegetated regions are clearly visible while watching the time-lapse replays of these sequence in color. A principal objective of Dr. Turner's research is the mapping, or quantitative documentation of these areal changes. Consequently, we have been investigating various methods of displaying radiance profiles along selected transects (see Fig. 5a and b) as well as creating binary thematic masks (thresholdings) of scenes which appear representative of the scenes observed visually and at the same time be amenable to measurement.

Dr. Turner visited SRI during the week of 14 May and used the ESIAC to study his imagery (MSS 5 and 6) of desert vegetation for the Tucson area. Registered color sequences for ten available ERTS cycles were prepared for two major test regions designated as Avra Valley and Old Baldy. A procedure was evolved for deriving thematic masks in accordance with the ratio of radiances observed in MSS 6 to those observed in MSS 5. Bare desert soil exhibits a ratio very close to unity. It was found that the typically sparse desert vegetative cover increases the bare desert ratio to values between unity and 2.0. With reasonable care in compensating for film density variations during the process of scanning with the ESIAC, it has proven feasible to generate thematic masks which are TRUE for all areas where the radiance ratio exceeds threshold values as small as 1.1 or 1.2. The newly-added color space display described in the Hardware section



a) RADIANCE PROFILE ALONG MINE TRANSECT IN ARIZONA DESERT USING ERTS-1 FRAME 1102-17280-5. [Vertical Scale and dc Level same as for Grey Scale Shown in Panel b]



b) VIDEO SIGNAL RESPONSE FOR SCAN ACROSS CALIBRATION GREY SCALE OF POSITIVE TRANSPARENCY OF ERTS-1 FRAME 1102-17280-5 USED FOR PANEL a, ABOVE

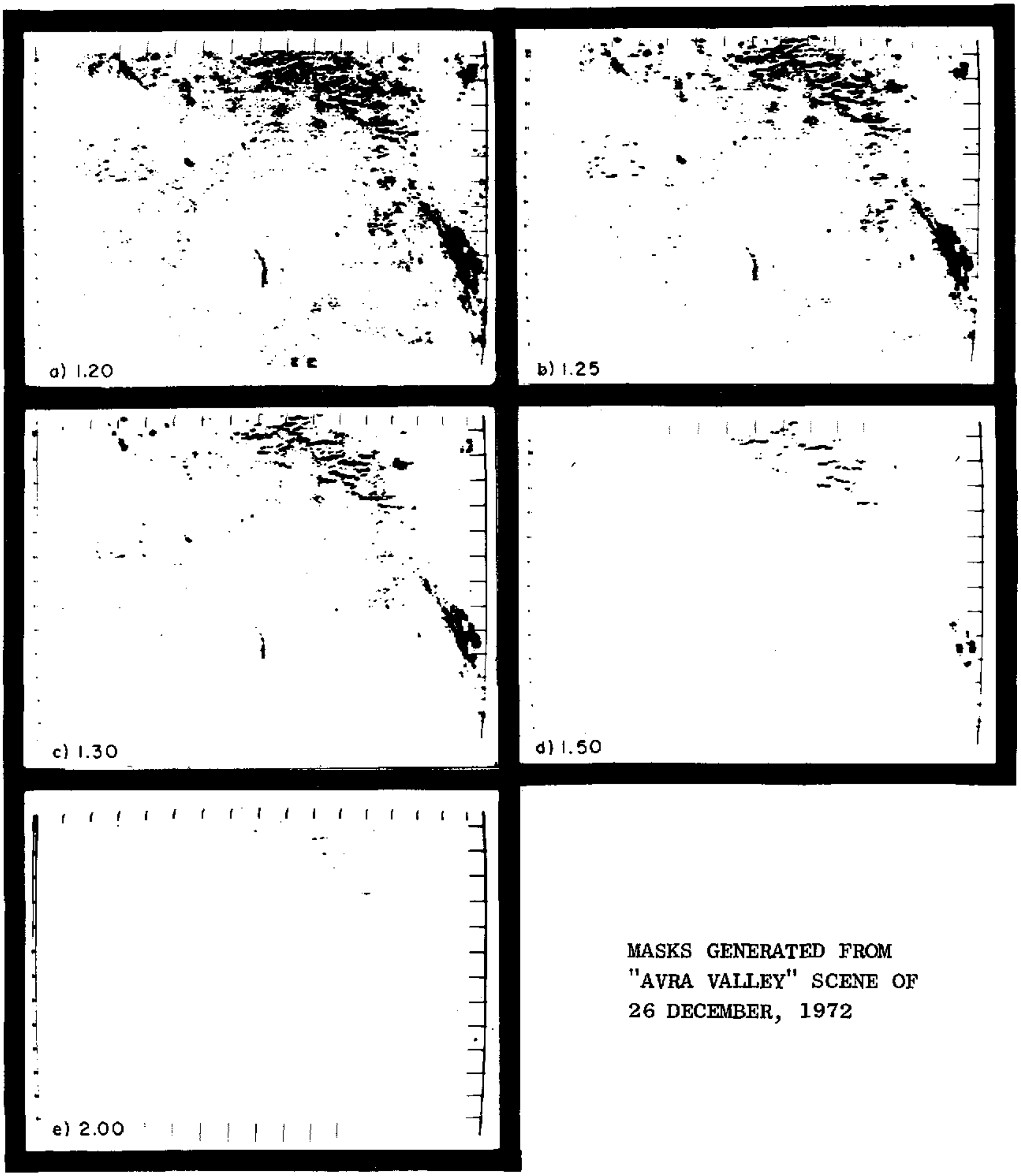
FIG. 5 EXAMPLES OF RADIANCE PROFILE DISPLAYS of this report will greatly facilitate manipulation of the ESIAC to make various ratio rationed thematic extractions.

To arrive at an acceptable ratio, thematic masks of vegetative cover were derived for several cycles using a number of ratios, viz. 1.2, 1.25, 1.3, 1.5 and 2.0. The ability to skip rapidly back and forth through registered color sequences was of great help in arriving at an acceptable threshold for the ratio. An example of the change in cover that results from these small ratio changes is shown in Fig. 6. It is obvious that less vegetative coverage is delineated as higher ratio values are used. Based on known distributions of cover at this time Dr. Turner decided that the ratio of 1.25 was the more acceptable one. This value was used to derive measurement values for the Serrita, Mine and Mile-Wide areas and will be used for the evaluation of the Sabina Canyon and Benson areas.

To facilitate further checking against ground truth, and to provide documentation for the work, a set of registered images, overlays, and radiance profiles for each area measured was prepared by photographing the ESIAC displays. A typical set of data provided to Dr. Turner included the following items:

1) Scene Photo
2) Scale (Kilometer) Grids
3) Transect Overlay
4) Calibrated Radiance Profile
5) Ratio Overlays (Diazo Transparencies)
6) Area Measurements for the Ratio Overlays.

c) <u>For Dr. E. J. Pluhowski (IN058)</u> USGS W. R. D. Arlington, Virginia: Dr. Pluhowski visited SRI on March 20-22, 1973 bringing with him all available cloud-free 70-mm cloud separation transparencies for the Lake Ontario area through January, 1973. ESIAC was used to enhance and display sediment plumes and shoreline erosion. No additional work was submitted by Dr. Pluhowski during this six-month period.



MASKS GENERATED FROM "AVRA VALLEY" SCENE OF 26 DECEMBER, 1972

Fig. 6 EXAMPLE OF THEMATIC MASKS GENERATED USING SELECTED RATIOS OF BAND 6 (MSS-6) TO BAND 5 (MSS-5). [Ratio values indicated in each panel]

d) For Dr. Estes F. Hollyday (IN389) USGS W. R. D., Nashville, Tennessee: Dr. Hollyday first visited SRI on April 3, 4 and 5. Virtually all of that time was devoted to working with ESIAC to display imagery brought by him and the basic objective was to determine the degree to which ESIAC could be used in enhancing, identifying, and mapping healthy vegetation exposed water surfaces, snow and massed works of man. At that time little repetitive data was yet available for time lapse analysis.

In August Dr. Hollyday, accompanied by Mrs. Virginia Carter again visited SRI. A significant amount of Dr. Hollyday's current work involves the measurement of integrated clear area from binary transparencies (theme foils) that have been prepared by non-SRI personnel either photographically or manually. While such measurements can be made with the ESIAC, a brief side excursion was made to investigate the possibility that equivalent or superior accuracy for this particular measurement might be achieved with far simpler and less expensive equipment. Accordingly, a separate set-up utilizing a photographic enlarger and an integrating photometer was prepared for Dr. Hollyday and used by him in measuring areas within specific drainage basins for several sets of previously-prepared thematic extractions. Calibration checks of this procedure using carefully measured apertures of various sizes, varified that accuracies of ±2% of the basin area were easily attainable. This is better than the ±5% which is believed to be required in order to make meaningful streamflow regression estimates and appears to be many times more accurate than the actual thematic extraction can be made by any process evolved to date. This measurement accuracy is also higher than can currently be achieved with the ESIAC, though this situation will soon be improved through improvement in camera scan linearity and lens aperturing effects.

As a result of these tests, a recommendation was made that in the future any significant quantity of area measurements of this type be made with the simpler equipment. This should permit us not only to fulfill our original contractual obligation to measure some 1800 foil areas, but also to provide more ESIAC time to Dr. Hollyday for refining the criteria by which the original thematic extractions are made.

Mrs. Virginia Carter used the ESIAC to analyze wetlands on ERTS imagery taken in the vicinity of Charleston, South Carolina, and Norfolk, Virginia. Several sequences were entered on the ESIAC console including one over the Dismal Swamp, one over the Santee River Swamp, and one over the coastal marshes in the Charleston estuary and along the South Carolina Coast. Mrs. Carter was the first investigator to work with the new two-dimensional color space capability (described in the Appendix). A number of sample measurements of various marsh components were made in order to examine the usefulness of a 2-band ratio technique as a possible method for separation of wetland from other scene elements. These data are presently under study by Mrs. Carter.

e) For Dr. C. G. Reeves (IN168) Texas Tech University, Lubbock, Texas: A census of the playa lakes (3405) in the West Texas area designated by Dr. Reeves was completed. No additional work was submitted by Dr. Reeves during this six month period.

f) For Dr. F. H. Ruggles:

No work submitted during this period.

D) FUTURE PLANS

1. Hardware

No major hardware changes are anticipated for the remainder of the project. Certain small changes or refinements to the ESIAC equipment that may be necessary to increase speed and/or accuracy of measurement will be done as needed to accommodate special requirements of the participating investigators.

2. Data Processing

The bulk of the work for the remainder of the project will be largely confined to acquiring data using techniques that have evolved over the past six months and in refining our quantitative calibration procedures. Specifically, this work includes:

a) For Dr. M. F. Meier:

1) Study the time sequence of snow cover for additional basins in the North Cascade region plus Mt. Rainier (all of which are vegetated areas) and one basin in Alaska (still to be selected) that is a non-vegetated area.

2) Determine the accuracy with which snow can be measured, considering the effects of seasonal changes and surface conditions upon snow appearance, and/or spectral response.

3) Use ESIAC to study glaciers, i.e., their shape and dimension, changes in size (especially edges), terminal moraines, glacial surges and also the extent and changes of snow on the glacier. Both advantages and disadvantages of using the electronic system (ESIAC) for these purposes are to be delineated. [In creating time sequences of glacier changes, the Hubbard Glacier will be used plus those other galciers that promise useful results.] A meteorological analysis will be conducted primarily with respect to occurrence of snow or snow melt on the glaciers and the Alaska basin selected for measurement.

b) For Dr. R. M. Turner:

1) Delineate through thematic masks, derived at a Band 6/Band 5 ratio of 1.25: the desert vegetation in Sabina Canyon area and Benson area for cycles 1 through 15.

2) Continue to extend the measurements through additional cycles or evaluate a new site yet to be selected.

c) <u>For Dr. E. F. Hollyday and Virginia Carter:</u>

New work will await the evaluation of results of the working visit to SRI in August.

d) <u>For Dr. C. G. Reeves:</u>

Scheduled to visit on September 21, 1973

e) <u>For E. J. Pluhowski:</u>

Scheduled to visit on October 16, 1973

f) <u>For Dr. F. H. Ruggles:</u>

Unknown at this time.

3. <u>Visits and Presentations</u>

The following visits and presentations by SRI personnel are scheduled during the next six-month period:

1) Presentation of a paper (see abstract) by Mr. S. M. Serebreny and Dr. P. A. Davis at the 54th Annual Meeting of American Meteorological Society, Honolulu, Hawaii, January 8-11, 1974.

ABSTRACT

SATELLITE APPLICATIONS TO WATER STORAGE

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A technique has been developed for estimating basin precipitation (rain and snow) by using operational meteorological satellite data. Best results are expected for cumulative precipitation totals over periods of 5 days or longer, but reliable evaluation of results is a problem. The study has expanded to an analysis of the rate of change of surface water storage, with initial emphasis on the rate of change of snowpack during the melt season as viewed by ERTS-1 imagery. Estimated rates of change of storage and

*Assistant Director, Atmospheric Sciences Laboratory

**Program Leader, Satellite Radiometric Data Applications runoff are influenced by precipitation occurring between successive ERTS views. On the other-hand, accurate future accounting of storage changes and the processes of water loss will enable better evaluation of estimates of cumulative precipitation.

Typical problems in the assessment of snowpack extent and rate of change are examined by comparison with snow course measurements at specific locations in the basin. Sequences of ERTS images are displayed as are select imagery from the NOAA-2 satellite.

A color movie will be presented using a series of ERTS frames to illustrate the use of electronic techniques to depict changes with time of the areal coverage of snow as well as provide quantitative measurement of these changes.

2) Attendance by Mr. S. M. Serebreny at the conference on Recent Status of Accomplishments, at Goddard Space Flight Center, NASA, October 23 through November 2, 1973 to report on Contract NAS5-21841, entitled "Study of Time-lapse Data Processing for Dynamic Hydrologic Conditions."

3) Presentation of a paper (see abstract) by Mr. W. E. Evans at Western Snow Conference, Anchorage, Alaska, scheduled for April 1974.

ABSTRACT

PROGRESS IN MEASURING SNOW COVER FROM ERTS IMAGERY

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A hybrid of digital and analog analysis techniques are being employed to determine the accuracy with which snow area and temporal change in snow area can be determined from satellite imagery.

The principal analysis tool is an Electronic Satellite Image Analysis Console (ESIAC) which permits display of

*Senior Research Engineer, Electronics and Radio Sciences Division time-lapse sequences of color composite images on a color TV monitor. Binary snow maps are generated electronically, superimposed on the image display for any necessary human editing, then measured for area in a digital counter. Results are checked against high altitude aircraft photography.

Bright snow is relatively easy to measure. Snow in shadow or illiminated at low incidence angles is harder to identify unambigously. Several potential solutions for this problem and for the problem of a snow-tree mixtures are being studied. A time-lapse movie covering a full year of ERTS imagery of a typical mountain snowfield will be shown.

4) Attendance by Mr. W. E. Evans at the EROS Conference to be held at Sioux Falls, South Dakota, October 30 through November 1, 1973.

APPENDIX

DESCRIPTION OF TWO-DIMENSIONAL COLOR SPACE DISPLAY

W. E. Evans, Senior Research Engineer

This section describes an additional display capability which has recently been added to the ESIAC. The new display is an oscilloscope with matched wideband x and y deflection amplifiers. It is connected as shown in Figure A-1. This arrangement provides a dynamic version of the two dimensional scatter diagram frequently used for analysis of two-band radiometry.

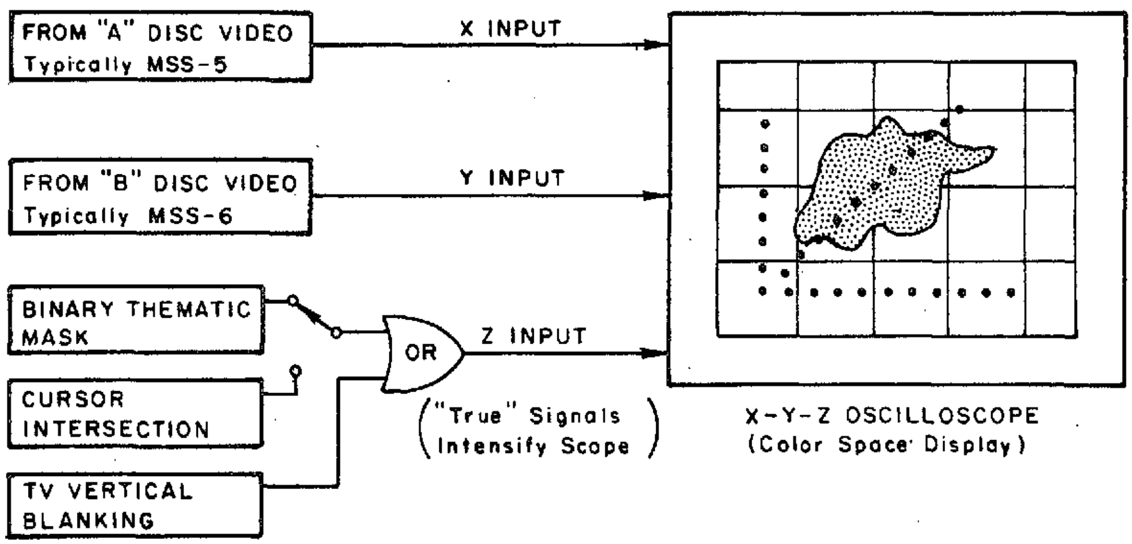
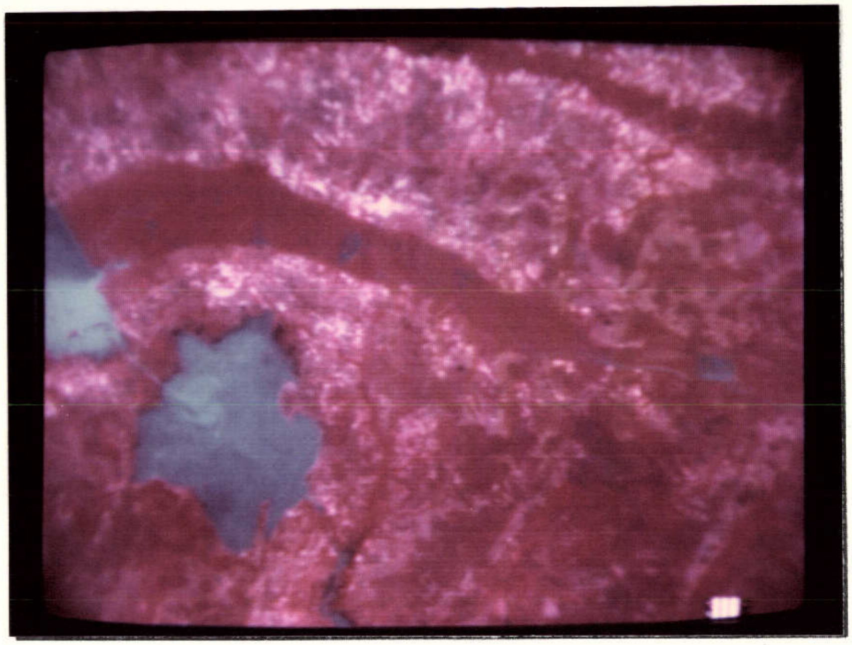


FIG. A-1 OSCILLOSCOPE CONNECTIONS FOR COLOR MAPPING DISPALY

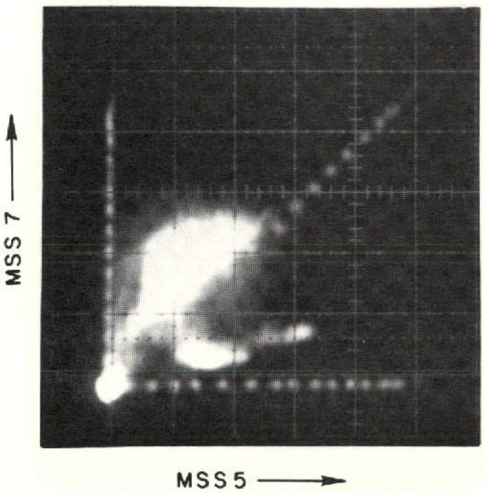
While any two synchronous video signals can be so displayed, a typical situation is for the ESIAC to be used to display a time lapse sequence of additive pseudo-color images derived from two different MSS channels. A particularly useful combination for many applications is to display on the color TV monitor one of the infrared images (MSS 6 or MSS 7) in red and one of the visible images (MSS 4 or MSS 5) in cyan. While this display is being scanned in normal TV raster fashion, the spot on the x-y ocsilloscope is being continuously positioned in accordance with the instantaneous responses in the two image channels. We will refer to the TV display as the "image space display" and to the latter x-y oscilloscope display as the "color space display." All points in the image which generate equal responses in the two channels will be distributed ("mapped") along a 45° diagonal line in the x-y color space display. Zero response is located at the origin in the lower left corner.

For a complete image, the brightness distribution over the color space display provides a measure of the color or energy distribution for the image; that is, two-band video information is converted into a two dimensional scatter diagram. Considering specific applications, a heavily vegetated scene for example will generate a scatter diagram ("map") with most of its energy above and to the left of the diagonal (Fig. A-2). Water bodies normally map into the lower right region (also Fig. A-2). Scenes containing significant areas of snow or clouds produce maps showing appreciable energy distributed along the "neutral" diagonal (Fig. A-3). In Fig. A-3c the color space display was unblanked only during scan of one of the brighter clouds, and shows that the cloud generates a near-maximum response in both channels.

By providing intensification (z axis modulation) to the color map display only during the cursor intersection period any designated portion of the ERTS image becomes identifiable on the color map and its color coordinates (percent response in each of the two shannels) can be



a) PHOTOGRAPH OF IMAGE SPACE DISPLAY (color TV monitor) FOR PORTION OF ERTS SCENE 1261-15274 SANTEE RIVER SWAMP, SOUTH CAROLINA 10 APRIL 1973 (MSS-7 SHOWN IN RED, MSS-5 IN CYAN. PICTURE HEIGHT = 53 km)



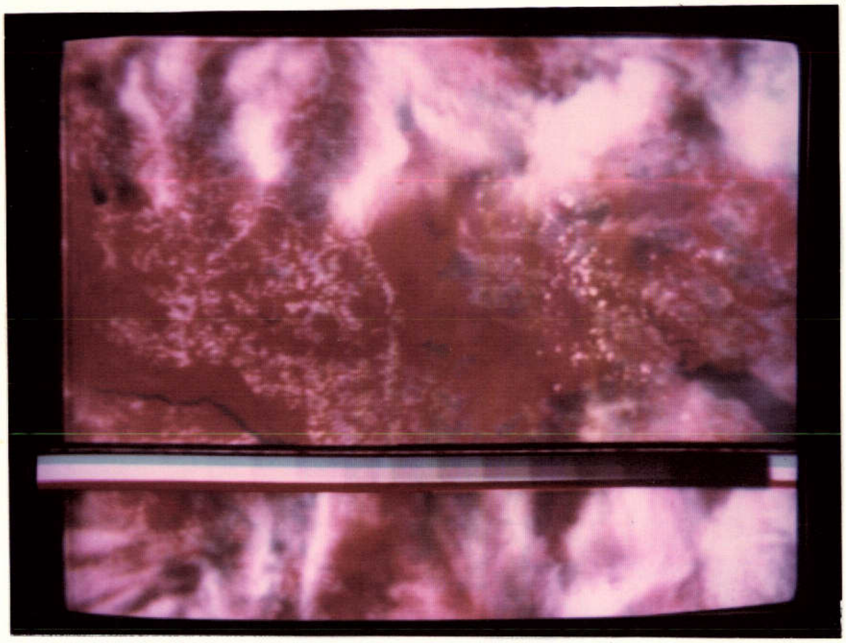
b) COLOR SPACE DISPLAY FOR SCENE OF (a)

Note heavy concentration of energy in the mid-brightness red region above and to the left of the 45° diagonal.

Note also two lesser energy concentrations in the mid and low brightness cyan region below the diagonal.

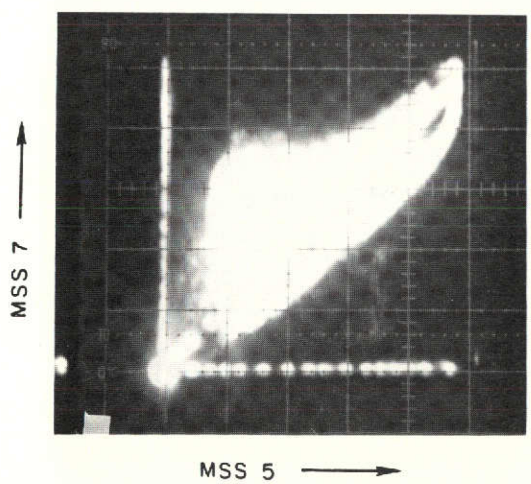
Dots on axes are from ERTS gray scale tablet (not visible in panel a).

FIG. A-2 TWO ALTERNATIVE DISPLAYS OF ERTS MULTISPECTRAL DATA (Each can be Viewed in Time Lapse on ESIAC)

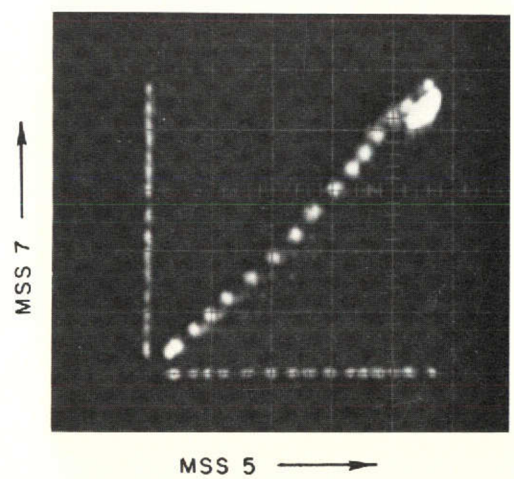


a) PHOTOGRAPH OF IMAGE SPACE DISPLAY (Color TV Monitor) FOR PORTION OF ERTS SCENE 1313-15150, DISMAL SWAMP, NORTH CAROLINA/VIRGINIA 1 JUNE 1973(MSS-7 SHOWN IN RED, MSS-5 IN CYAN. PICTURE HEIGHT = 53 km)

(Image has been "rolled"(displaced vertically) to show calibration gray scales stored on disc during the normal TV vertical retrace interval).



b) COLOR SPACE DISPLAY FOR ENTIRE SCENE OF (a). NOTE HEAVY ENERGY CONCENTRATION ALONG 45° DIAGONAL DUE TO CLOUDS.



c) SAME COLOR SPACE DISPLAY AS (b) EXCEPT UNBLANKED ONLY DURING A PORTION OF ONE OF THE BRIGHT CLOUDS.

FIG. A-3 EXAMPLES OF IMAGE SPACE DISPLAY AND COLOR SPACE DISPLAY read, (Fig. A-4). Leaving the cursor positioned over a vegetated area, while cycling through a long sequence of registered images provides a rapid and dramatic portrayal of the changing spectral responses of the vegetation patch as it proceeds through its seasonal changes.

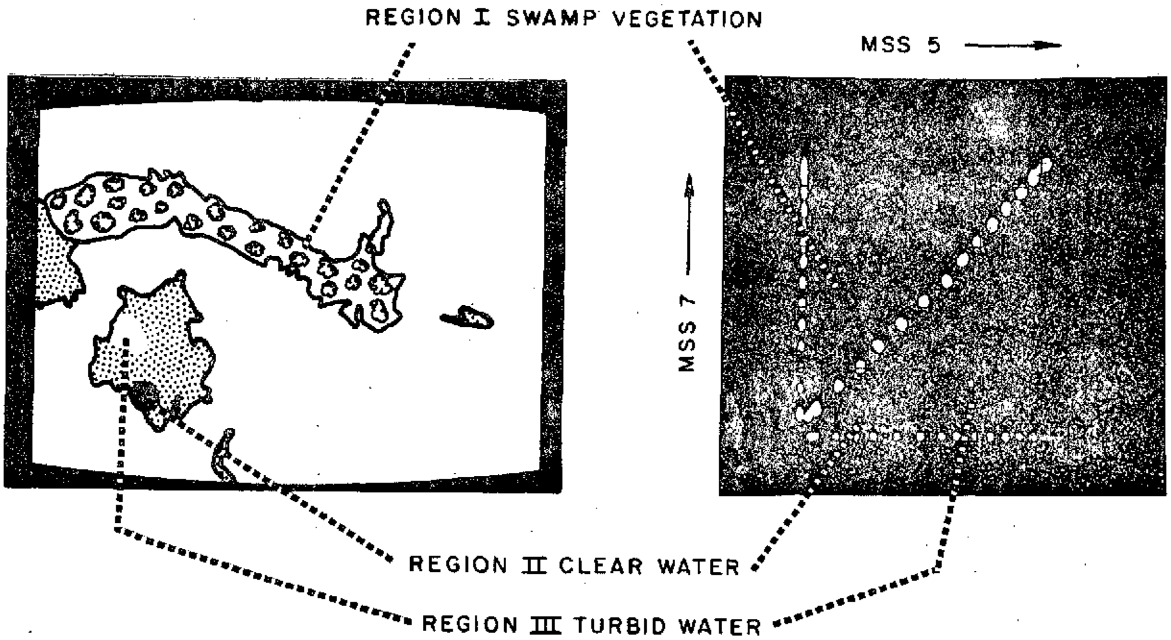


FIG. A-4 COLOR SPACE DISPLAY OF SPECTRAL SIGNATURES FROM THREE SELECTED SMALL GEOGRAPHICAL REGIONS WITHIN SCENE OF FIG. A-2

Reference and Calibration Axes

The dotted axes and 45° diagonal in the color space displays (see Figs. A-2 through A-4) are an additional bonus resulting from the the image grey-scale tablets are handled in the ESIAC. This process will now be described.

In order to prevent the loss of a recorded radiometer scale reference when small "zoomed in" section of full ERTS frames are being viewed, it has become standard practice to record a minimum zoom image of the full grey scale table of the source of transparency during the 1.5 millisecond vertical retrace period of the main image. This is valuable recording capacity which would otherwise be wasted.

Prior to recording, the camera controls are adjusted to compensate as much as possible for batch-to-batch variations in film processing; i.e., an attempt is made to normalize the grey scale gain, offset, and linearity. All grey scales are recorded at a fixed magnification (to utilize nearly the full width of the raster) regardless of what magnification may be used for the scene data in the main portion of the frame.

After this dual recording process, the grey scales may be viewed on the picture monitors by intentionally misplacing the vertical sync to "roll" the image vertically. Normally, however, it is not necessary to view the recorded grey scale as an image. Its principal purpose is to provide amplitude calibration for the video waveforms; and for this use it can be accessed at any time with the console's cursor-controlled line-selector oscilloscope.

Additionally, the grey scale data will show up on the x-y color map display as a line of dots since this display is not blanked during the vertical retrace period. In fact it is desirable to actually intensify the color map during the picture vertical retrace interval in order to emphasize the color coordinate axes.

The desired effect of having the reference data be at 0°, 45° and 90° on the color map is achieved by recording the two grey scales slightly misregistered in the vertical direction. Because of the intentional misregister, there will be a brief period (several scan lines) during which only the Band 6 grey scale will be scanned, another brief period during which only the Band 5 grey scale will be scanned and a third brief period during which both grey scales are scanned simultaneously (see Fig. A-3a). It is during this latter period that a color <u>image space</u> display will show a neutral grey scale, and the 45° diagonalline will be generated on the x-y (<u>color space</u>) display.

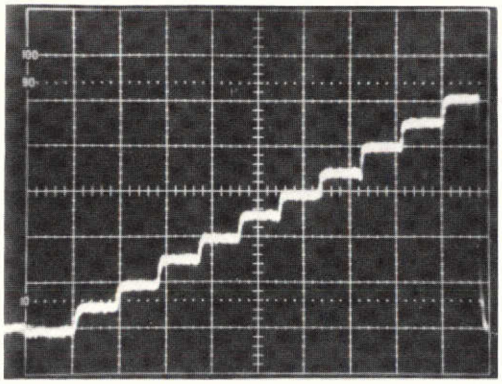
By reading the x and y coordinates of an area relative to the axial dots generated by steps on the film grey scale tablet (interpolating when necessary), two-band radiometric values for the area can be specified in terms of absolute values; e.g., in Watts-Meter^{-2}-Steradian^{-1}, with a minimum error due to amplitude non-linearities in the photographic and TV processing steps.

Synthetic Test Pattern

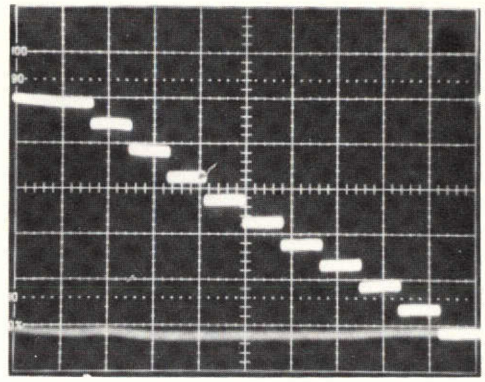
In order to exercise the full gamut of spectral combinations possible with the recording, display and classification equipment, a special two-channel test signal generator was constructed. Its output video waveforms, along with associated image space and color space displays, are shown in panels a-d Figure A-5. When combined into a two-primary additive color display, (Fig. A-5) the test pattern appears as an 11 x 11 checkerboard color palate presenting samples of all possible colors and brightness achievable with the two primaries used or, alternatively, showing the result of all possible combinations of responses in two input channels. Maximum red color saturation is in the upper left corner, maximum cyan saturation is in the lower right corner, and a scale of neutral greys runs from black at the lower left corner to maximum white at the upper right corner.

Since the display spends an equal amount of time (slightly less than 1% of the total) in generating each color patch, the color map transformation of the synthetic test pattern in an 11 x 11 array of equal intensity dots (Fig. A5-f). This full-gamut dot pattern greatly facilitates adjustment of the various video thresholding and slicing circuits provided in the ESIAC for generating binary masks of various image classifications or themes. By watching the dot display as the thresholding levels for the thematic mask are changed, the system can be quickly tailored to respond only within some particular subregion of the color space.

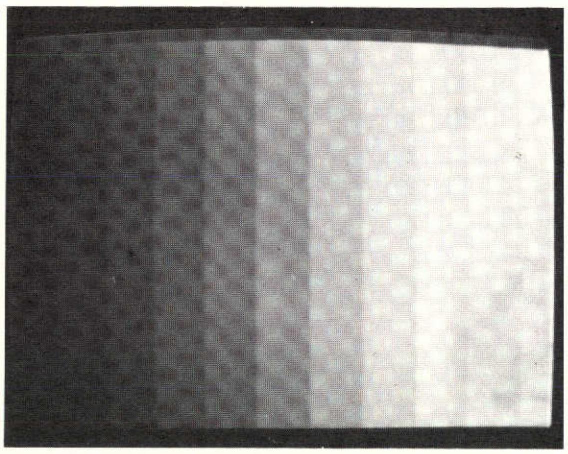
The several panels of Figure A-6 illustrate some of the thematic



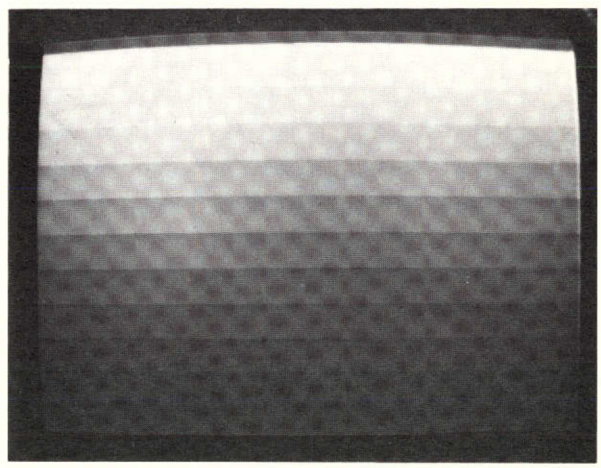
a) CYAN CHANNEL VIDEO WAVEFORM



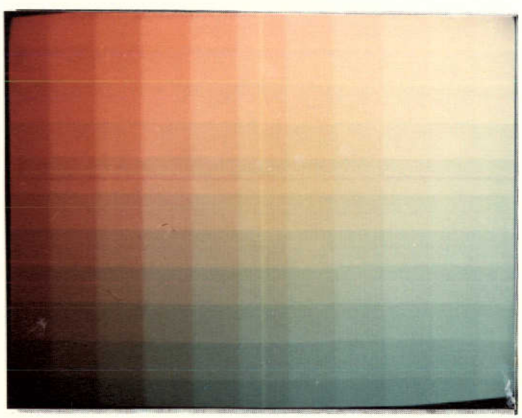
b) RED CHANNEL VIDEO WAVEFORM



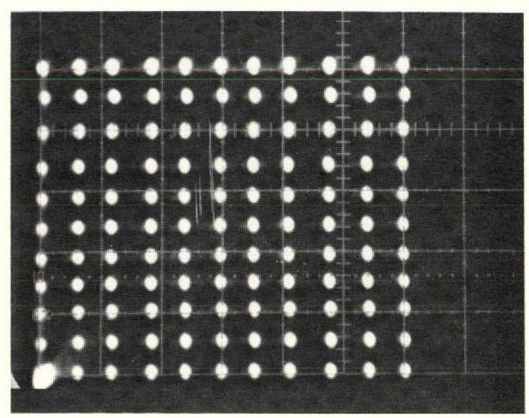
c) CYAN CHANNEL IMAGE DISPLAY



d) RED CHANNEL IMAGE DISPLAY

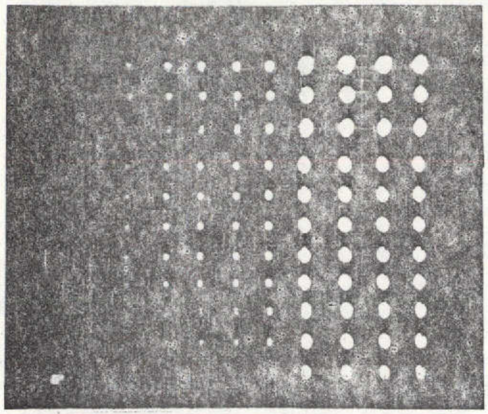


e) COLOR COMPOSITE DISPLAY
(Image Space)

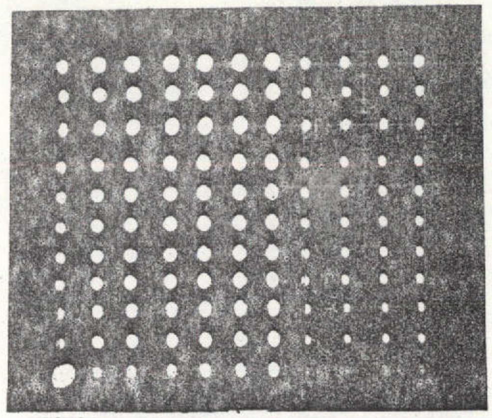


f) COLOR SPACE DISPLAY

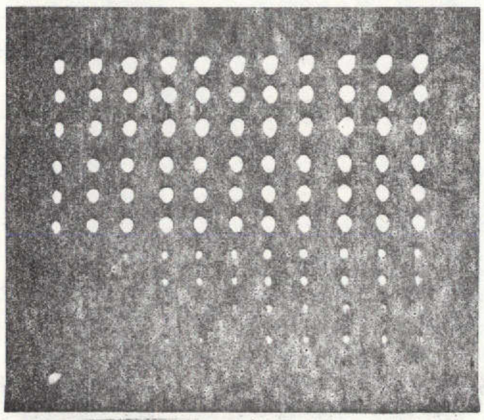
FIG. A-5 VARIOUS DISPLAYS OF THE TWO-CHANNEL SYNTHETIC TEST PATTERN



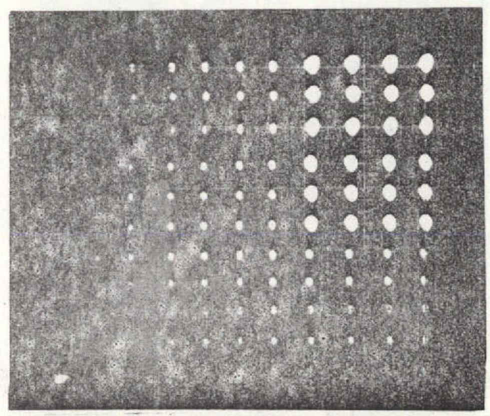
a) $B5 > 0.65$



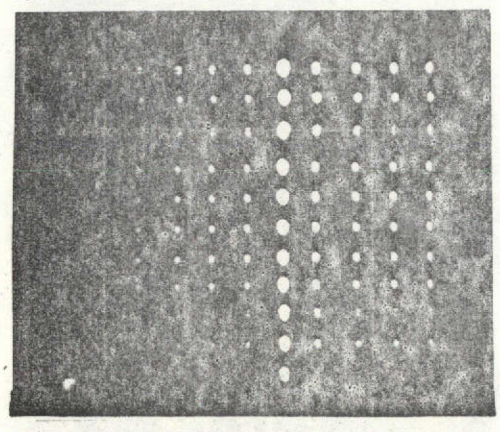
b) $B5 < 0.65$



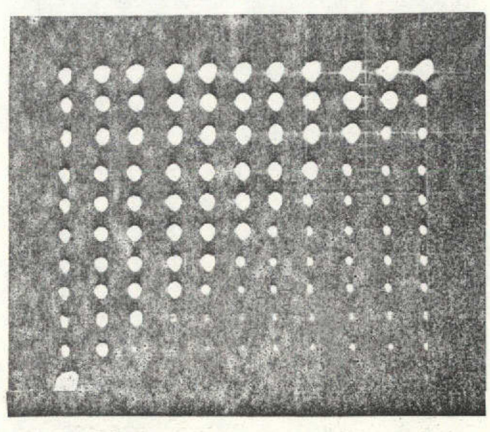
c) $B6 > 0.45$



d) $(B5 > 0.65) \bullet (B6 > 0.45)$

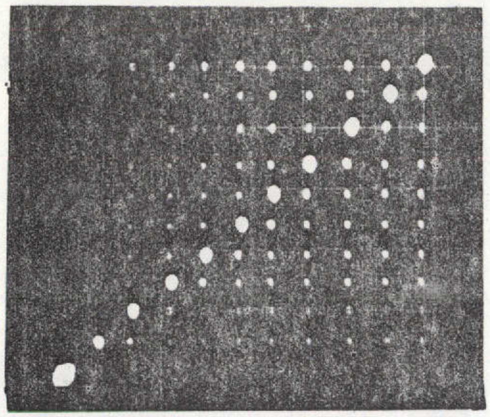


e) $(B5 > 0.55) \bullet (B5 < 0.65)$

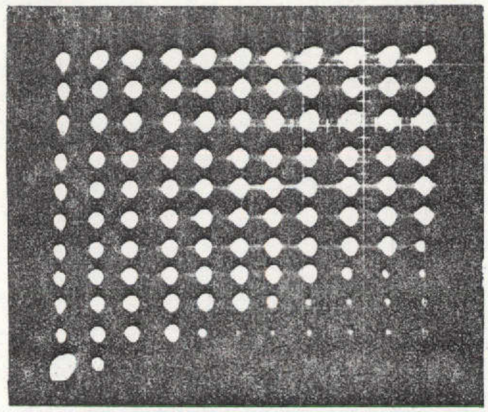


f) $\frac{B6}{B5} > 1$

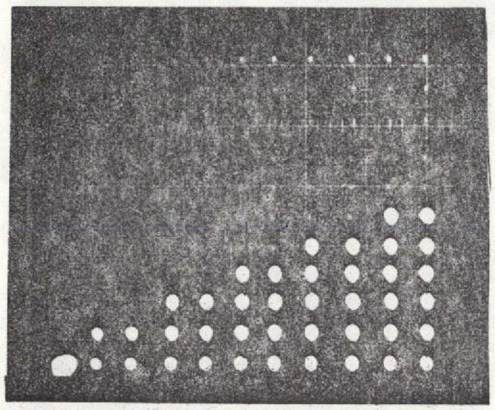
FIG. A-6 A SAMPLING OF THE SPECTRAL CLASSIFICATIONS AVAILABLE BY VARIOUS LOGICAL COMBINATIONS OF THE VIDEO LEVEL DECISION CIRCUITS (LDC's) IN THE ESIAC. [In Each Case the Color Map is Intensified for All Input Signal Combinations Satisfying the Logical Equations Given. B5 = MSS-5 = Horizontal Deflection, B6 = MSS-6 = Vertical Deflection]



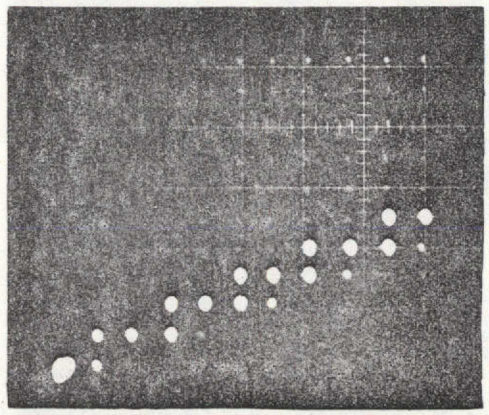
g) $(B6 > B5 - 0.05)\bullet(B6 < B5 + 0.05)$



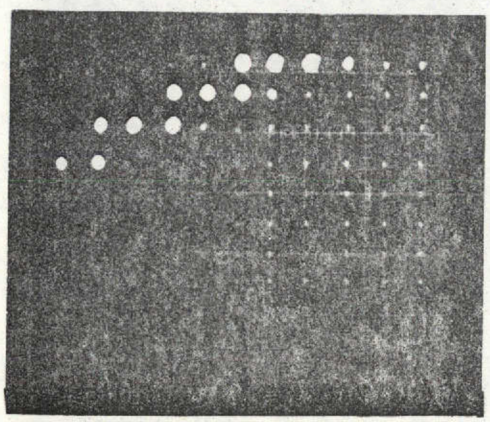
h) $B6 > (0.5\ B5 - 0.05)$



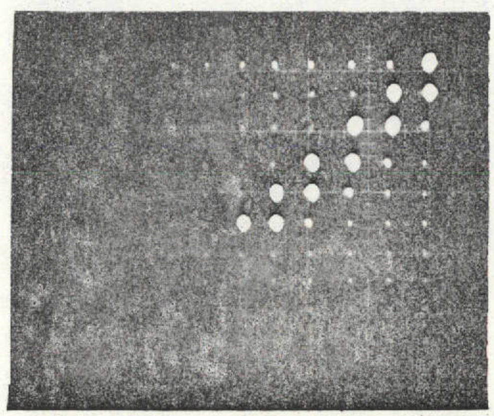
i) $B6 < (0.5\ B5 + 0.05)$



j) $(B6 > (0.5\ B5 - 0.05))\bullet(B6 < (0.5\ B5 + 0.05))$



k) $B6 > (0.05 + 0.6)\bullet(B6 < (0.05\ B5 + 0.8))$



ℓ) $((B6 > (B5 - 0.15))\bullet(B6 < (B5 + 0.05))\bullet(B6 > 0.45)$

FIG. A-6 (Continued)

extractions which are possible through manipulation of the video slicing and thresholding controls. In all cases, those spectral combinations which pass the classification tests (i.e., which can generate TRUE or white areas in the thematic mask) are shown intensified.

The same binary video signal used here for intensification of the color space display will generate a two dimensional thematic mask when displayed in image space. Figure A-7 is a black and white reproduction of the color image space display containing a superimposed (intensified)

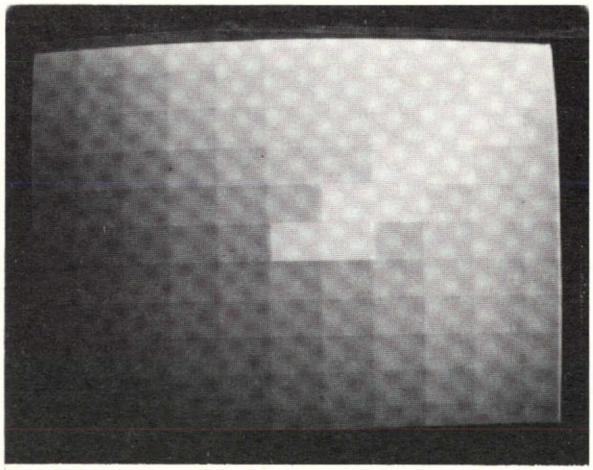


FIG. A-7 BLACK AND WHITE REPRODUCTION OF TEST PATTERN ON COLOR MONITOR (image space display). [A Superimposed Video Thematic Mask Corresponding to the Condition of Fig. 6ℓ Delineates those Areas of the Image which Meet the Classification Conditions]

thematic mask for the same conditions used to generate Figure A-6ℓ.

These conditions might be used, for example, to extract from a color scene all the bright greys and whites (i.e., which hopefully, would correspond to all the areas of bright snow and clouds).

Application

It is believed that this highly interactive addition to the ESIAC analysis capability will be of significant help to investigators interested in converging upon a quantitative description of the dynamics of a phenomenon of interest to them.

Decisions about the efficacy of various thresholding, slicing, and ratioing algorithms can be made while watching the results on a registered time series of scenes displayed immediately, and simultaneously, in both image-space and color space. Once a suitable classification algorithm has been found, first-order quantitative results for each scene can be read quickly from the ESIAC area-measuring readout. Then, if the ultimate in precision is required, and Computer Compatible tapes are available, the same algorithm can be programmed for digital processing of the CCT's with reasonable assurance that the results will be meaningful.